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ABSTRACT

This paper presents a study designed to clarify the role of perceptual-attentional factors in the development of conservation, and relates the results to procedures for assessing conservation. Subjects were 192 first and second graders. The number and type of perceptual cues in the conservation of liquid quantity task were systematically varied. In general, nonconservation increased in kindergarteners as the number of cues increased. In contrast, first graders were affected very little by the perceptual conditions. Both grades showed a specific training effect of borderline significance under certain conditions. The results suggest that the development of conservation involves several levels which vary from an early understanding of invariance which can be demonstrated only under facilitating conditions, to a final, stable, generalized concept of quantity. (Author/CS)

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PERCEPTUAL INFORMATION IN CONSERVATION: EFFECTS OF SCREENING

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Abstract

Variations of the screening method developed by Piaget and Frank made it possible to systematically vary the number and type of perceptual cues in the conservation of liquid quantity task. In general, nonconservation increased in kindergarteners as the number of cues increased. In contrast, first graders were affected very little by the perceptual conditions. Both grades showed a specific training effect of borderline significance under certain conditions. The results suggest that the development of conservation involves several levels which vary from an early understanding of invariance which can be demonstrated only under facilitating conditions, to a final, stable, generalized concept of quantity.

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PERCEPTUAL INFORMATION IN CONSERVATION: EFFECTS OF SCREENING

Patricia H. Miller and Karen H. Heldmeyer

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In tests of conservation, Piaget requires a child to ignore several misleading perceptual cues and provide a logical explanation before he diagnoses a child as a conserver. His test of conservation of liquid quantity, for example, presents many cues: different heights and widths of various containers and their liquids, movement of the water as it is poured from one container to another, color of the water, etc. The child must decide which of these many cues, if any, are relevant to quantity. Nonconservers typically "center on" or attend to the water level and believe that the higher the water level, the larger the amount. Conservers, according to Piaget, ignore the various cues or use them in the service of a cognitive operation--reversibility, compensation, identity, etc.,--to arrive at a conservation answer.

There is a growing concern among psychologists that the standard tests of conservation are making performance unnecessarily difficult and even masking the child's true competence, leading to a false diagnosis of nonconservation in some children. The information-processing requirements are great, perhaps even overwhelming for some children. This position is supported by a growing body of research on perceptual-attentional factors in conservation. Two tentative conclusions have emerged: a) attention to stimulus dimensions plays a role in conservation performance (e.g., Gelman, 1969; Miller, 1973), and b) perceptual supports for conservation facilitate conservation performance (Miller, Heldmeyer, & Miller, 1973; Whiteman & Peisach, 1970). Both conclusions suggest that in the typical conservation tests there are salient stimulus dimensions which "pull" both nonconservers and some new conservers towards a nonconservation

answer. Systematically removing these dimensions should reveal a clearer picture of exactly how perceptual information influences conservation performance in young children. This was the strategy of the present study.

The study used the "screening" technique developed by Piaget (1971) to study mental imagery and subsequently used as a conservation training technique by several others. Screening involves blocking part or all of the stimuli from the view of the child. In a well-known study by Frank, reported by Bruner, Olver, and Greenfield (1966), children were given conservation training aimed at inducing conflict between ikonic (perceptual) representation and symbolic representation. Part of the training involved pouring liquid from a visible container into a differently shaped container which was screened except for the very top of the container. After the conservation question was asked, the screen was removed and the conservation question repeated. On a subsequent posttest there was improved conservation performance among children aged 5, 6, and 7, but not aged 4. Although nearly all of the children gave conservation answers before the screen was removed, after the screen was removed four-year-olds regressed to a nonconservation answer based on the different water levels in the two beakers. This study has been criticized by Inhelder, Bovet, Sinclair, and Smock (1966) for not requiring logical explanations before classifying a child as a conserver and by Piaget (1967) for not including certain checks for pseudoconservation. Also, Strauss and Langer (1970) have failed to replicate Frank's training effect.

The present study was not designed to use screening as a conservation training technique or to replicate the Frank experiment, but rather to use screening as a device for reducing the number of perceptual cues. There were, however, some important comparisons with the Frank study. One question was whether totally screening the liquid would produce a high proportion of "conservation" answers as in the Frank study. Another question was whether children of different ages would respond differently to the screen and its removal,

as in the Frank study. Kindergarten and first grade were chosen because most children should be moving from nonconservation to conservation during this period. A further question, not studied by Frank and virtually unexplored in the conservation literature, was whether the extremity of the transformation (how much change in height and width) would influence performance. Large changes should be more salient than smaller changes, thus increasing the likelihood of nonconservation.

The purpose of the study, then, was to clarify the role of perceptual-attentional factors in the development of conservation and to relate these results to procedures for assessing conservation. This problem was studied by systematically varying the number and type of perceptual cues.

Method

Subjects

There were 192 children tested, 108 kindergarteners and 84 first graders with mean ages of 5 years, 10 months and 6 years, 10 months respectively. The children were from two predominantly white, middle class schools in Ann Arbor, Michigan. An additional four children were not used as subjects because they failed the verbal pretesting. Children were randomly assigned to three conditions, with approximately the same number of boys and girls in each.

Apparatus

The pretest for comprehension of the verbal terms used four clear plastic bags of uncooked popcorn, two middle-sized bags, one larger bag, and one smaller bag. The experiment proper used five sizes of cylindrical glass containers, each holding one quart of water with one inch of space remaining at its top. The standard container was 15.2 cm. tall and 9.4 cm. wide. When water was poured from the standard, it was fitted with a clear plastic spout. Two other beakers were shorter and wider than the standard, though in differing degrees; they were 10.5 cm. tall and 11.9 cm. wide (sw) and 5.2 cm. tall and 18.4 cm. wide (SW). Two other beakers, 21.3 x 7.8 cm. (tt) and 27.4 x 6.8 cm.

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(TT), were progressively taller and thinner than the standard. Thus, beakers sw and tt represent a moderate change from the standard, while beakers SW and TT involve a more extreme transformation. A screen (45 cm. wide, 48 cm. deep, and 91 cm. tall) with an opaque pull curtain in front was also used in testing.

Procedure

The children were tested individually in a small room at the school. While the E was establishing rapport with the child it was mentioned that he would be asked the same questions several times. This was intended to avoid any impression that repeating a question during testing meant the child's answer was wrong. Each child was given a pretest for the verbal terms to be used in the actual testing. The child was shown the middle-sized bag of popcorn (the standard) and then the other three bags. He was asked successively to indicate which bag contained more, less, and the same amount of popcorn as the standard. If the child was not totally correct, the experimenter made paired comparisons. If necessary, the basis for the correct answer was explained to the child, after which the original questions were repeated. Any child who had more than an initial minor difficulty with the verbal terms was not included in the study.

There were three conditions, one with a typical conservation procedure, one with fewer perceptual cues, and one with several levels of reduced perceptual cues. The conditions had certain common elements as follows: Each trial in every condition began by showing the child two identical standards nearly filled with water. The child was asked if they contained the "same amount" of water. If necesary, the amounts were adjusted until he agreed to their equality. One standard was then poured into a different container, but the conditions varied in whether this container was visible or screened. After the transformation (pouring), the child was asked, "Do we both have the same amount of water or does one of us have more?" After his answer he was asked, "How did you figure that out?" The act of pouring the liquid back into the original standard in preparation for the next trial was never visible to the child.

When the water was poured behind a screen, the experimenter's arm and both beakers were screened from the child. The child could, of course, hear the water being poured. After the standard was emptied, it was returned to its spot near the other standard which was still full.

The conditions varied in the amount of perceptual information available. After establishing the equality of the two standards on each trial, the procedures were as follows:

1. Typical test of conservation (C). This condition has the most perceptual cues.
   - Trials 1-4 On each trial, water was poured into a different container (sw, tt, SW, TT), visible to S. The conservation question was asked.
   - Trial 5 This was the same as trials 1-4, except the water was poured into an identical standard.
2. Screen plus empty glass (Sc). This condition has fewer perceptual cues.
   - Trials 1-4 On each trial, water was poured into a different container, which was completely screened. An identical but empty container was shown to the child and described as "the same as the one behind the screen." The conservation question was asked.
   - Trial 5 This was the same as trials 1-4, except the water was poured into a standard.
   - Posttests 1-3 These were typical tests of conservation. The containers were the same as those in trials 1, 2, and 5 respectively.
3. Screen, show empty glass, remove screen (ScR). The number of perceptual cues gradually increased throughout a trial.
   - Trial 1a Water was poured into a different container which was completely screened. The conservation question was asked.
   - Trial 1b An empty container, identical to the one behind the screen, was shown and described as "the same as the one behind the screen." The conservation question was asked.
   - Trial 1c The curtain was raised, revealing the container of liquid, and the conservation question was asked.

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Trial 2, a-c This was the same as trial 1, a-c, except that a different container was used.

Trial 3, a-c This was the same as trials 1 and 2, except water was poured into a standard.

Posttests 1-3 These were typical tests of conservation, using the same containers as in trials 1, 2, and 3 respectively.

Part of the function of conditions C (typical test of conservation) and Sc (screen plus empty glass) was to serve as a control for ScR, the main condition. Trials 1b and 2b of condition ScR provide perceptual information which is essentially the same as in condition Sc, i.e., the only perceptual cues regarding the transformation are found in the empty standard (after pouring) and the empty container identical to the one behind the screen. Thus, a comparison of condition Sc and parts b of condition ScR should reveal any carryover effects from other parts of condition ScR, while still permitting a clean comparison of condition Sc with condition C. Condition C provides a baseline of conservation for comparison with the main trials and posttests in the other two conditions. Thus, any training effect, though not expected, would be evident. This design was used rather than a conservation pretest which might bias performance on the main tests. These posttests for conservation followed the same procedure as in condition C.

The trials in which water was poured from one of two standards into yet a third identical standard were intended as a check for any response bias, e.g., continuing to answer, as in the earlier trials, that the amount changes when it is poured. A response bias is always possible in any test which asks similar questions several times.

There were four orders of presentation of the containers in conditions C and Sc--sw-tt-SW-TT, tt-sw-TT-SW, SW-TT-sw-tt, and TT-SW-tt-sw. There also were four orders in condition ScR--sw-tt, tt-sw, SW-TT, and TT-SW. The four orders were counterbalanced within each grade in each condition.

Scoring

There were two kinds of criteria for conservation--a conservation judgment (CJ) and a conservation judgment accompanied by an adequate explanation (CE). A conservation judgment was credited if the child believed that the containers held the same amount after the transformation. Adequate explanations included compensation, previous equality, irrelevancy of transformation, reversibility, and no addition or subtraction. Two raters independently scored the responses. The agreement with respect to whether an explanation was adequate was 94% and the agreement with respect to type of adequate explanation was 98%. When several trials were involved a child was classified as a conserver if he always gave a conservation judgment and at least half of his judgments were accompanied by adequate explanations. Nonconservers always gave nonconservation judgments and all other children were classified as transitional.

Results

There were no significant differences due to sex, order of presentation of containers in conditions C or Sc, or the particular container used. Thus, the extremity of the transformation apparently is not an important factor, at least for the range of stimuli used.

The condition of most interest is condition ScR in which several degrees of perceptual information were presented. Figure 1 shows that first graders

Insert Figure 1 about here

performed better over all in this condition than the kindergarteners. More interesting, however, is the fact that the two grade levels had distinctly different patterns of response. Their level of performance was nearly the same on the first part of the first trial, but diverged thereafter. On trial 1a in which there was essentially no perceptual information about the transformation because the container was screened, the majority of children in both grades asserted conservation. However, then the kindergarteners were shown the empty beaker identical to that behind the screen (trial 1b), most of them switched

to a nonconservation answer, a significant change, McNemar $\underline{X}^2$s (1) = 13.47 and 13.07 for CJ and CE scores respectively, $\underline{p} < .001$. When the screen was removed, kindergarteners, surprisingly, showed a slight increase in conservation which was significant for CJ scores, binomial test, $\underline{p} = .03$, but not for CE scores. On trial 2a, kindergarteners had a high level of conservation judgments, but it was lower than on trial 1a, $\underline{X}^2$ (1) = 5.79, $\underline{p} < .05$. In contrast to CJ scores, CE scores were low and remained low throughout trial 2. Thus, experience on trial 1 affected conservation explanations more than conservation judgments on trial 2a. As on the first trial, CJ scores dropped sharply in trial 2b, binomial test, $\underline{p} = .008$, but the decrease from 2b to 2c was not significant. On the conservation posttests, kindergarteners had approximately the same CJ and CE scores as on parts b and c averaged over trials 1 and 2.

In contrast, the first graders were relatively unaffected by the changing amounts of perceptual information over the two trials, $\underline{p}$ (all McNemar $\underline{X}^2$s) $> .05$. However, first graders demonstrated more conservation on the posttests than at any other time in the session. This result was unexpected.

There was a relationship between performance on the posttests and the main trials. Children assessed as conservers on the posttest had more CJ and CE responses over the six parts of the two main trials than did the nonconservers, $\underline{t}$s (52) for CJ and CE = 11.78 and 11.47, $p < .001$ (grades combined).

Table 1 provides a comparison of the performance of each grade in each condition. In some cases only the first two trials of conditions C and Sc were used for statistical comparisons; thus, the table includes proportions for both the first two trials and all four trials.

Insert Table 1 about here

Performance on the various parts of condition ScR could be affected by experience with earlier parts of the condition. Any such carry-over effect can be identified by comparing parts of condition ScR with comparable parts in conditions Sc and C in which a cleaner assessment was possible. All trials in

condition Sc and trials 1b and 2b of condition ScR were similar in that the child saw an empty container identical to the full container behind the screen. In neither grade was there a significant difference in the proportion of nonconservers versus transitional conservers and conservers on the first two trials of condition Sc and trials 1b and 2b of condition ScR. Thus, there was no significant carry-over on trials 1b and 2b. Similarly, one can compare condition C, the regular conservation condition, with trials 1c and 2c of condition ScR in which all containers of water are visible. The only significant difference was for kindergarteners on trial 1c which had significantly fewer nonconservers than on the first trial of condition C, $\underline{X}^2$ (1) = 5.06, $\underline{p} < .05$. Thus, the first two parts of trial 1 in some way influenced performance on the third part.

A final question concerning condition ScR is whether experience with that condition resulted in improved conservation performance on the posttests. A training effect was not expected because the experience was so brief (about 15 minutes). A comparison of nonconservers versus transitionals and conservers in in conditions C (first two trials) and ScR (conservation posttests) yielded a chi-square which was of borderline significance for kindergarteners, $\underline{X}^2$ (1) = 3.21, $\underline{p} < .10$, and first graders, $\underline{X}^2$ (1) = 3.81, $\underline{p} < .10$. The increase among kindergarteners was due entirely to a movement of subjects from the nonconserver to the transitional conserver category. For first graders, the main change was an increase in the proportion of conservers from .36 in condition C to .71 in the ScR posttest. In light of the nearly significant training effect, especially in first graders, a delayed conservation posttest was given to the few first graders who were available for retesting on the same conservation tasks. Of nine conservers on the immediate posttest, 8 were conservers and one was transitional two weeks later. Thus, the conservation performance was maintained.

A comparison of conditions C and Sc reveals that the fewer misleading perceptual cues, the more conservation among kindergarteners only. The proportion

of transitional conservers plus conservers was significantly higher in condition Sc than condition C among kindergarteners, $\underline{X}^2$ (1) = 5.93, $p < .05$, but not first graders. It should be mentioned that there was no training effect in condition Sc. The proportion of nonconservers was not significantly different on the first two trials of condition C and the conservation posttest trials of condition Sc in either grade. Finally, in condition Sc there was a relationship between performance on the posttest and earlier parts of the condition. Children who conserved on the posttest had more CJ and CE responses over the four main trials than did the nonconservers, ts (59) for CJ and CE = 9.96 and 11.28, $\underline{p} < .001$ (grades combined).

As expected, nearly all children believed that the amount did not change whenever the water was poured into a beaker identical to the standard. (Several children gave inequality answers because they mistakenly thought there were slight differences in the sizes of the beakers or their water levels.) Thus, when the containers looked the same, regardless of previous performance children said the containers had the same amounts; there did not seem to be a response bias.

Discussion

The most salient result is that kindergarteners and first grades are affected differently by the amount of perceptual information. Many of the kindergarteners appear to hold two conflicting beliefs--a belief in nonconservation and a belief in conservation which is supported by a logical explanation. Which belief is expressed depends on the amount or type of perceptual information in the testing situation. In particular, the assertions of equality dropped sharply when they were shown an empty container identical to the one behind the screen, presumably because it gives them information about the heighth and width of the beaker. Similarly, there was more conservation in condition Sc in which on all trials children were shown an empty container identical to the one behind the screen than in the regular conservation

condition, in which children saw the changing water level as well as the beaker size. Thus, the more perceptual information, the less conservation.

In contrast, the first graders are relatively unaffected by the stimulus conditions. Children who are conservers to begin with tend to remain conservers and nonconservers remain nonconservers. The belief in conservation is strong enough to withstand the "perceptual seduction" (Bruner, Olver,and Greenfield, 1966) of the changing water level.

Both grades, but especially the first graders, showed a slight training effect (borderline significance). This improvement following such a brief experience was unexpected and it should be pointed out that the training may be specific to the stimuli--the conservation posttest used the same stimuli as seen earlier in that condition. The slight training effect may give some support to Bruner's position that a procedure involving the removal of a screen is an effective conservation training device. Of course, this training effect is not necessarily due to conflict between ikonic and symbolic codes as Bruner contends.

Piaget's (1971) work with the screening technique focused on the role of the anticipation of water levels after transformation, which involved the use of mental images. He believed that nonconservers may appear to be conservers in the screening situation only becuase they expect the water level to remain the same. Thus, they are "pseudoconservers." In the present study, subjects were not questioned about water level because it was felt that this might bias them towards using water level to make their judgments. However, there is evidence which questions Piaget's conclusion. Both kindergarteners and first graders gave a high proportion of conservation judgments <u>with logical explanations</u> on the first presentation of the completely screened transformation (trial 1a of condition ScR). All but one of these logical explanations were of the "previous equality" or "addition-subtraction" type. Thus, the belief in invariance was not simply based on a belief that the container behind the screen

had the same water level as the visible container. If logical explanations reflect operations, then these children possessed the underlying cognitive operations normally attributed only to "true conservers". However, many of these children did not use these operations later in the experiment and regressed to nonconservation. It may be that these children did not always realize that the operations they possess were relevant to the situation. It is interesting that the two grades were equally able to give these explanations when the beaker was screened on trial 1a; the judgments of first graders were not more advanced than those of kindergarteners, even though first graders demonstrated much more conservation than kindergarteners on all later parts of the condition. An alternative position is that verbal logical explanations do not always reflect cognitive operations. In this case, the "conservers" could actually be pseudoconservers.

The results suggest that conservation of liquid quantity is not an all-or-none ability, but instead consists of several levels of understanding. That is, many young children considered to be nonconservers by the standard procedures may have a rudimentary understanding of the invariance of liquids which they can demonstrate under facilitating conditions. In this study, the first presentation of the completely screened transformation facilitated conservation by not providing distracting and irrelevant perceptual cues. It may also be that the reduced total load of information to process allowed children to use their knowledge of conservation. The majority of children expected invariance when there was no perceptual information to the contrary. At first this belief may not be based on a logical judgment and thus is pseudoconservation, in Piaget's system. Most of the children in this study were at a higher level in which they have logical support for their beliefs, as shown by their explanations. This rudimentary understanding, though genuine in some sense, is fragile, difficult to elicit, and easily shattered by the perceptual pull of irrelevant features. It may be several months or years before the concept

becomes fully generalized to all perceptual conditions. The most mature level of conservation would be demonstrated in the standard test of conservation in which there are irrelevant cues. In between these lowest and highest levels of understanding may be several levels which vary in what perceptual cues can be ignored and how easily judgments can be supported by adequate explanations. The presence of these levels is clearer for kindergarteners than first graders.

There are, then, several implications for the assessment of conservation. It is inaccurate (or at least misleading) to consider a child to be a "conserver" or "nonconserver". A child can "have" conservation in different senses. The demonstration of the ability to conserve is dependent on the procedures and criteria. Approximately two-thirds of the children in the condition with changing perceptual information (ScR) appeared to be nonconservers sometimes and conservers at other times. A more accurate and refined test of the conservation of liquid quantity would consist of a number of items which systematically vary along a scale with full perceptual support for conservation or complete lack of irrelevant cues at one end and no perceptual support or many irrelevant cues at the other end. The present study is a start towards this goal.

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Unnumbered Footnote

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Table 1

Proportion of Nonconservers (NC), Transitional Conservers (Tr) and Conservers (C) in Each Grade and Condition

Condition		Main Test			Posttest (2 trials)		
		NC	Tr	C	NC	Tr	C
Kindergarten							
C	Trials 1-4	.78	.08	.14			
	Trials 1-2	.81	.06	.14			
Sc	Trials 1-4	.47	.19	.33	.61	.08	.31
	Trials 1-2	.53	.17	.31			
ScR	a (2 trials)	.24	.44	.32	.58	.28	.14
	b (2 trials)	.64	.19	.17			
	c (2 trials)	.53	.33	.14			
First grade							
C	Trials 1-4	.46	.18	.36			
	Trials 1-2	.50	.14	.36			
Sc	Trials 1-4	.29	.21	.50	.46	.00	.54
	Trials 1-2	.32	.18	.50			
ScR	a (2 trials)	.18	.29	.54	.21	.07	.71
	b (2 trials)	.32	.18	.50			
	c (2 trials)	.32	.21	.46			

Figure Caption

Figure 1. -- Percentage of kindergarteners and first graders giving conservation judgments (CJ) and conservation judgments accompanied by adequate explanations (CE) in condition ScR.

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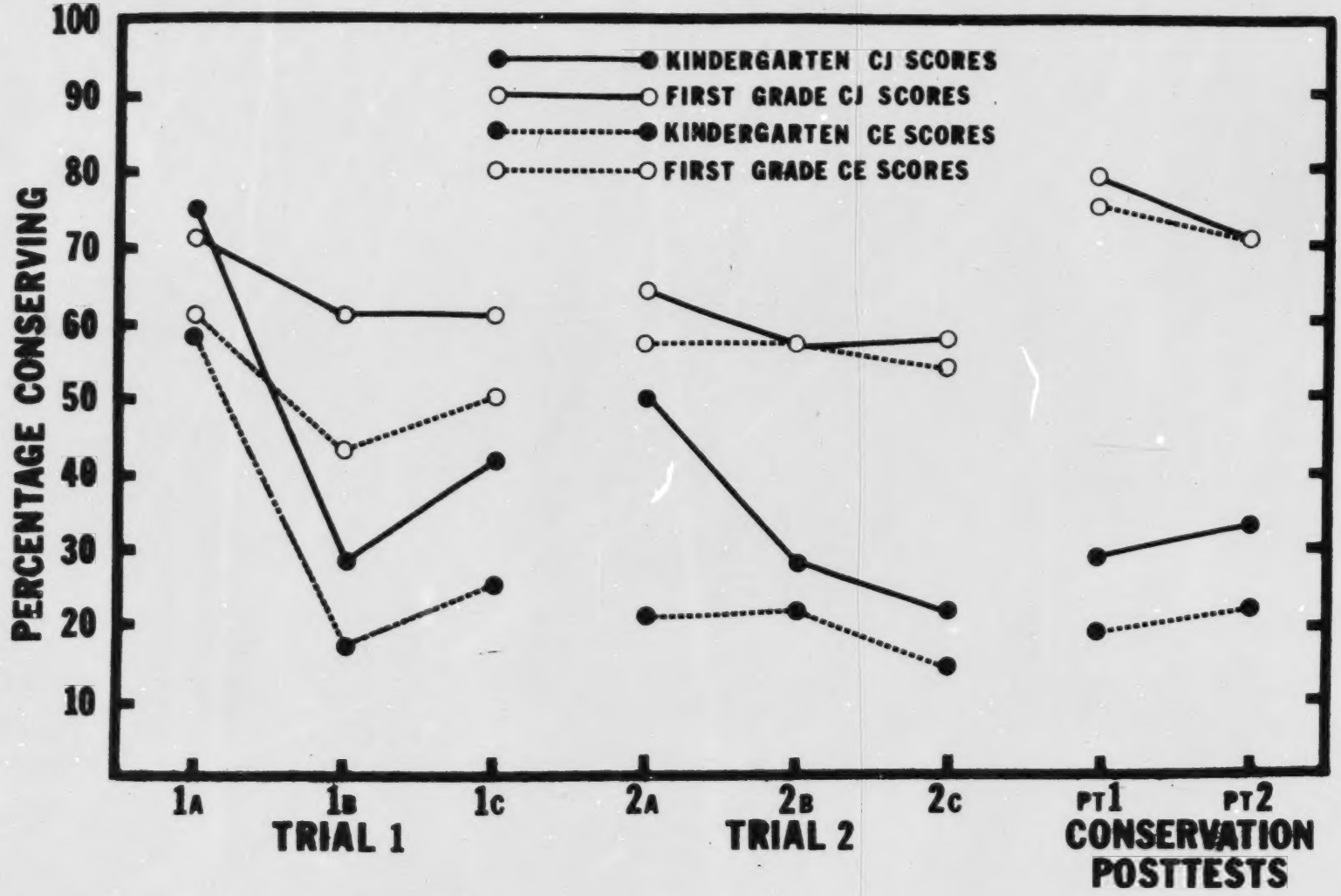
KINDERGARTEN CJ SCORES
FIRST GRADE CJ SCORES
KINDERGARTEN CE SCORES
FIRST GRADE CE SCORES
PERCENTAGE CONSERVING
100
90
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1A
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PT1
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TRIAL 1
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CONSERVATION POSTTESTS

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